



**"A Media Maniac's Review
of
Removable Storage Media"**

THIC

January 23, 1996

Linda Kempster

Storage Media Specialist

IIT Research Institute

301-918-1037

lkempster@mtc.iitri.com



THE GRAND CHALLENGE

On the Sea

In Space

On Land

"Coming soon to an office near you!"



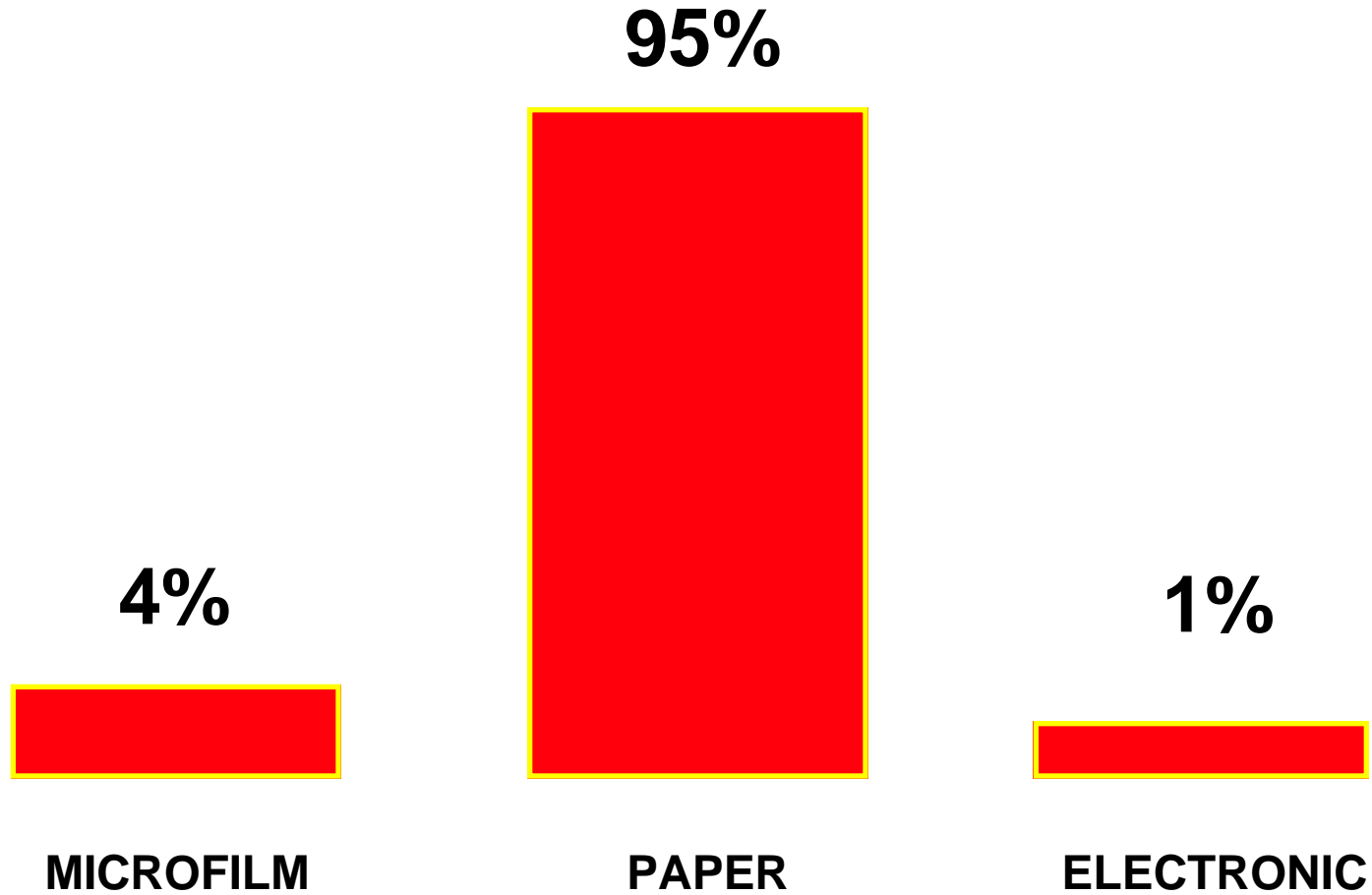
THE CRITICAL VALUE OF INFORMATION MANAGEMENT

"When accurate, timely, concise information is delivered on a consistent basis to the right person, that person becomes more knowledgeable. When a person becomes more knowledgeable, they become more productive and efficient, and can make quality decisions. Job satisfaction and morale improves. As a result, the company can create and deliver a higher quality product with better price/performance. The profits of the company rise and an environment is established enabling the attainment of corporate goals."

(Larry Hendershot)



ELECTRONIC STORAGE MEDIA





"GIVENS" TO SET THE STAGE

Easy numbers:

1,000 Megabytes = 1 Gigabyte (GB)

1,000 Gigabytes = 1 Terabyte (TB)

1,000 Terabytes = 1 Petabyte (PB)

1,000 Petabytes = 1 Exabyte (EB)

Average document image requires 50 KB of storage

1 GB capacity holds 20,000 document images

(Scanned @ 200 dpi and compressed at 10:1)

Four-drawer file cabinet holds 10,000 documents

1 GB capacity replaces 2 file cabinets

ASCII or COLD page requires 2 KB of storage

1 GB capacity holds 500,000 ASCII/COLD pages

A box of paper holds 5,000 sheets and weighs 50 lbs



SPACE STATION ERA

Future Requirements: Satellite Data

By 2000: EOS may produce 80 TB per year

After 2000: Space data may be 3,650 TB per year

Rates could approach 1200 Mbps

4 single downlinks @ 300 Mbps each

Impact Dilemma

NASA's ability to succeed will be impacted by the management and timely use of data

Data complexity increases with volume

Users: 10,000 scientists and 200,000 others

Number of new scientists & engineers declining



VHS CASSETTE

Media: High quality T-180 tape

Capacity: 21 GB

420,000 document images

(42 file cabinets)

10.5 Million ASCII/COLD pages

117 Reels of 180 MB 6250 tape

Transfer rate: 16 Mbps

End-to-end in less than 2 min

No rewind to dismount

V-48 JB: 1,008 GB in 19" rack



V-600 AUTOCHANGER

Broadcast industry standard Asaca autochanger

600 tapes = 12.6 TB

252 Million document images

(25,200 file cabinets)

6.3 Billion ASCII/COLD pages

Under 8 second access to any cassette

1 to 6 drives available

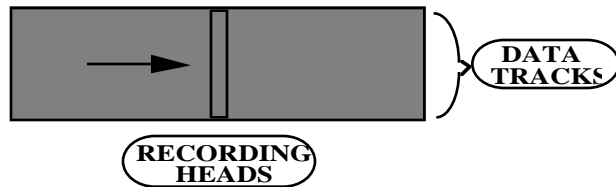
Desk-size footprint (18 sq ft or 1.8 sq meters)

**Replacement for 70,000 reels of 6250 tape or
12 optical disk jukeboxes @ 1 TB each**



MAGNETIC TAPE RECORDING

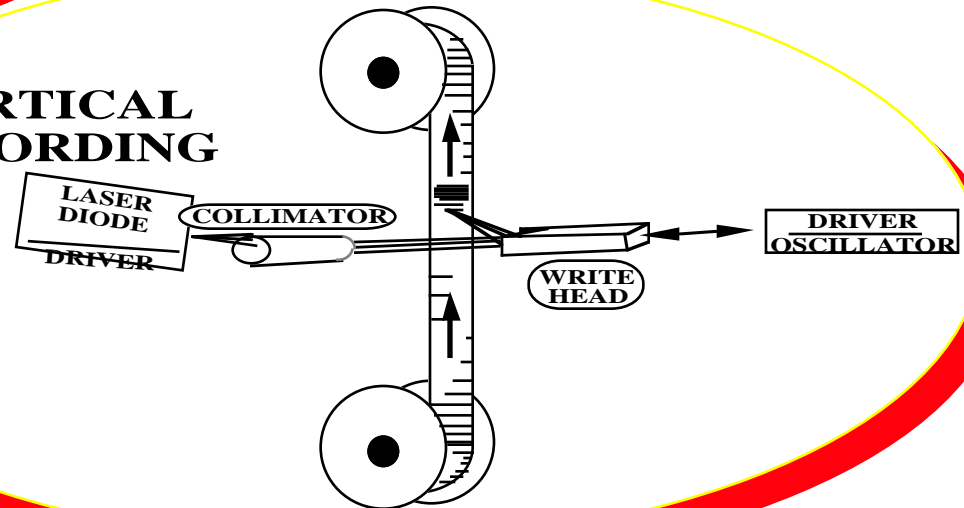
LONGITUDINAL RECORDING



HELICAL SCAN RECORDING



VERTICAL RECORDING





19 mm DIGITAL TAPE FORMATS

Broadcast

D-1

Max Trans Rate

220 Mbps

BER

1E-7 or -8

D-2

120 Mbps

1E-7 or -8

TV and video, analog data stream

Instrumentation

ID-1

400 Mbps

1E-10

Telemetry, continuous data stream

Computer Peripheral

DD-1

256 Mbps

1E-13

DD-2

120 Mbps

1E-15

Digital data storage, variable rates



DD-1 DIGITAL TAPE FORMATS

Media: Ferric oxide

<u>Size</u>	<u>Capacity</u>	<u>Images</u>	<u>ASCII/COLD</u>
Small	16 GB	320,000	8.0 M
Medium	40 GB	800,000	20.0 M
Large	96 GB	1,920,000	48.0 M

Transfer rate: 0 - 256 Mbps for data

Commercial drive: Sony

Library capacities: 2.3 TB, 13 TB, or 30 TB



DD-2 DIGITAL TAPE FORMATS

Media: Metal Particle

<u>Size</u>	<u>Capacity</u>	<u>Images</u>	<u>ASCII/COLD</u>
Small	25 GB	500,000	12.5 M
Medium	75 GB	1,400,000	35.0 M
Large	165 GB	3,300,000	82.5 M

Transfer rate: 0 - 120 Mbps

Commercial drives: Ampex and EMASS

Library capacities: from 5.5 to 806.4 TB



QUARTER INCH CARTRIDGE (QIC)

Media: Cobalt-modified ferric oxide

Capacity: 13 GB

260,000 document images

(26 file cabinets)

6.5 Million ASCII/COLD pages

Transfer rate: 12 Mbps

Access time: 30 sec



MINI-CARTRIDGE

Media: Barium ferrite

Capacity: 4 GB

80,000 document images

(8 file cabinets)

2 Million ASCII/COLD pages

Transfer rate: 7 Mbps

Access time: < 20 sec



TRAVAN CARTRIDGE

Media: Metal particle

Capacity: 4/95: 400 MB

1/96: 4 GB

80,000 document images

(8 file cabinets)

2 Million ASCII/COLD pages

Autoloaders: Various sources



8 mm CASSETTE

Media: Metal particle

Capacity: 7 GB

140,000 document images

(14 file cabinets)

3.5 Million ASCII/COLD pages

Bulk erase to reuse

Media vendor: Exabyte

Transfer rate: 4 Mbps

Avg Access: 85 sec



4 mm DIGITAL AUDIO TAPE (DAT) CASSETTE

Media: Metal particle

Capacity: 12 GB

240,000 document images

(24 file cabinets)

6 Million ASCII/COLD pages

Transfer rate: 6.2 Mbps

Seek time: 40 sec

3.5" drive in half-height 5.25" form factor

Many cassette loaders available



DIGITAL LINEAR TAPE (DLT) CARTRIDGE

Media: Metal particle-2

Capacity: 20 GB

400,000 document images

(40 file cabinets)

10 Million ASCII/COLD pages

Transfer rate: 24 Mbps

Seek time: 90 sec

Autoloaders available from several vendors



9 TRACK TAPE

Capacity of 6250 bpi: 180 MB

90,000 ASCII/COLD pages

Transfer rate: 3 Mbps

700 Million reels in use

Standard media for data interchange

New office environment drive

3.5 inches tall

30 pounds



HALF INCH TAPE CARTRIDGE

Cartridge name: 6790E or 3490E

Media: Chromium oxide

Capacity: 800 MB

16,000 document images

(1.6 file cabinets)

400,000 ASCII/COLD pages

Transfer rate: 52 Mbps

Tape loaders offered by a variety of vendors



NEXT GENERATION 34XX

Redwood from STK

Capacity: 50 GB

Transfer rate: 96 Mbps

Recording: Helical scan

Magstar from IBM (3590)

Capacity: 10 GB

Transfer rate: 72 Mbps

Recording: Longitudinal serpentine



LIBRARY STORAGE SYSTEMS

Seek time: 20-30 sec once loaded

STK 4410 - 6000 cartridges (max)

Footprint: 121 sq. feet, 8 Ft. tall

Library capacity: 4.8 TB

Wolfcreek - 500, 750, or 1000 cartridges

Panther - 200, 400, or 600 cartridges

IBM 3495 Library Dataserver

Maximum cartridges: 18,920

Library capacity: 15.1 TB

Footprint: 754 sq. feet, 7.8 Ft. tall

IBM 3494 - 210 to 3,040 cartridges



OPTICAL CARD

Current technology: 4.6 MB capacity

3 Floppy disks (1.4 MB)

92 document images

2,300 ASCII/COLD pages

Transfer rate: 0.16 Mbps

WORM technology

Low-cost distribution media



LASER PRINTED MICROFICHE

**Images: scanned at 300 dpi
printed at 24x, 42x, 48x, or 72x**

Either Group III or IV selectable

Printing 300 dpi images: 45 images per minute

Printing 200 dpi images: 60 images per minute

Benefits:

Microfiche readers are \$100 - \$200

Using approved film produces archivable images

Approximate OEM cost: \$68-350k



BERNOULLI REMOVABLE **MAGNETIC DISK**

Media: Barium ferrite

Capacity: 230 MB

4,600 document images

115,000 ASCII/COLD pages

Transfer rate: 16 Mbps

Seek time: 18 ms

Approved for encrypted data



COMPACT DISC READ ONLY MEMORY (CD-ROM)

Capacity: 650 MB

13,000 document images

(1.3 file cabinets)

325,000 ASCII/COLD pages

Transfer rate: 4.8 Mbps

Seek time: 269 ms

Interactive access to audio, images and text files

Best suited for mass distribution



CD STRENGTHS/APPLICATIONS

Recordable CD: CD-R (650 MB)

Transfer rate: 1.2 Mbps

Drives: \$999 Media \$5 (Sony)

Photo CD

Store 100 photos per disc (5 different resolutions)

Developed by Kodak and N.V. Philips

CD Jukeboxes

240 disc capacity - 3 second exchange time

Link 4 drives = 960 discs (624 GB)

64 unit tower - all discs available

500 disc unit available from Pioneer

1544 disc-unit available from ATG Cygnet



3.5" ROM DISC (O-ROM)

Capacity: 180 MB

3,600 document images

90,000 ASCII/COLD pages

Transfer rate: 3 Mbps

Seek time: 35 ms

Standards under development

Well suited for mass distribution



3.5" REWRITABLE OPTICAL DISK

Current capacity: 384 MB (MOST)

7,680 document images

(3 file drawers)

192,000 ASCII/COLD pages

Transfer rate: 6.5 Mbps

Avg seek time: 35 ms



OTHER 3.5" REMOVABLE MEDIA

Magnetic Disk Cartridges

Capacity: 1 GB (Iomega Jaz)

Bernoulli technology

Transfer rate: 44.2 Mbps

Access time: 12 ms

Capacity: 135 MB (SyQuest EZ135)

Transfer rate: 19.2 Mbps

Access time: 13.5 ms



2.5" MINIDISKS

Audio MiniDisc

74 min recording capacity

Shipped 300K by COB '93

By COB '94: 1M discs pressed per year

MD-Data: The Data MiniDisk

Capacity: 140 MB

2,800 document images

70,000 ASCII/COLD pages

2,000 frames of still-color images

Transfer rate: 1.3 Mbps

Direct m/o overwrite technology



1.8" & 2.5" REMOVABLE DISK CARTRIDGES

	<u>1.8"</u>	<u>2.5"</u>
Capacity (MB):	80.0	42.8
Transfer rate (Mbps):	10.4	15.6
Avg seek time (ms):	16.0	14.5
Media weight (gm):	18.0	28.0
MTBF (hours):	150k	100k



5.25" OPTICAL DISKS

Rewritable capacity: 2.6 GB

Sustained transfer rate: 2.2 Mbps

Popular rewritable technology: Magneto-optic (m/o)

Emerging: Phase-change overwrite (Plasmon PD)

650 MB - 6.9 Mbps (12 cm disk)

M/O direct overwrite

Nikon: 2.6 GB - 5.6 Mbps (13 cm disk)

Pinnacle: 4.6 GB - 80 Mbps (13 cm disk)

WORM capacity: 2.6 GB

Transfer rates: 2.2 Mbps



NIKON 12" ERASABLE DISK

Dual-head technology

Capacity: 8 GB

160,000 document images

(16 file cabinets)

4 Million ASCII/COLD pages

Transfer rate: 1.1 Mbps

Seek time: 72 ms

Jukebox: ATG Cygnet



DUAL HEAD 12" WORM DRIVES

Capacity: 12 GB from Philips LMS

240,000 document images (24 file cabinets)

6 Million ASCII/COLD pages

Transfer rate: 5.6 Mbps

Seek time: 95 ms

Jukeboxes: ATG Cygnet FileNet

Capacity: 15 GB from Sony (3Q96)

300,000 document images (30 file cabinets)

7.5 Million ASCII/COLD pages

Transfer rate: 21.6 Mbps

Seek time: 150 ms

Jukebox: Sony



DUAL RAPID CHANGER

Two 6-disk magazines

Capacity: 144 GB with 24 GB under-head

Removable disk packs for security

Can satisfy 50 - 60 requests per minute

Two dual units may be mounted in 19" rack

Avg disk exchange: 3 sec



14" OPTICAL DISKS

WORM

Capacity: 14.8 GB

296,000 document images

7.4 Million ASCII/COLD pages

Transfer rate: 8 Mbps

Access time: 700 ms

Rewritable (MIL-E-5400)

Capacity: 12 GB

240,000 document images

6 Million ASCII/COLD pages

Transfer rate: 24 Mbps

Access time: 195 ms



12" REWRITABLE LASER DISC

Double-sided rewritable discs

Vendors: Panasonic, Pioneer, Teac, and Sony
TEAC can access both sides without turning disc

1 million rewrites

10 year predicted life

108,000 still pictures stored in analog format

Similar to microfilm storage of non-digitized images
Recording technology to store color images



MATCH BOX (NT-1) DIGITAL MICRO CASSETTE

Media: Metal evaporated tape

Audio capacity: 120 minutes

45 minutes longer than CD-Audio

Data capacity: 612 MB

306 2-MB high-density floppies

Three 9-track tapes

12,240 document images

(4 file drawers)

305,000 ASCII/COLD pages

3600 lb of paper to print

Transfer rate: 670 Kbps



99.9% ACCURACY

- 1 Hour of unsafe water every month**
- 2 Unsafe plane landings at O'Hare each day**
- 16,000 Pieces of mail lost every hour**
- 21,000 Wrong prescriptions per year**
- 500 Wrong surgical operations every year**
- 50 Newborn babies dropped by doctors each day**
- 22,000 Checks incorrectly deducted every hour**
- 32,000 Missed heart beats per person every year**
- 2 Characters misread by OCR on each page of text**



DIGITAL PAPER GENERAL IMPACT

How big is a Terabyte?

999,999,999,999 bytes plus 1 (114 B punched cards)

1 TB of ASCII on paper would consume 42,500 trees

At 12 characters per inch, 1 TB of ASCII would circle the earth 56 times (1.4 million miles)

If ships contain 40 tons of paper, 1 TB of data would meet ASCII storage requirements for 62 heavy cruisers



OPTICAL TAPE REEL FEATURES

Media: Dye-polymer WORM

Capacity: 1,000 GB = 1 TB

20 Million document images

(2,000 file cabinets)

500 Million ASCII/COLD pages

Transfer rate: 24 Mbps

Write 32 bits simultaneously

Avg access time: 37 sec End-to-end: 60 sec

True mass production: creates 50 TB in 10 min



LASER OPTICAL TAPE

Media: Phase-change WORM optical tape

Transport unit: 3480-type cartridge

Capacity: 1.0 TB

20 Million document images

(2,000 file cabinets)

500 Million ASCII/COLD pages

Transfer rate: 120 Mbps

Seek time: 30 sec

Beta units out 3Q96



FUTURES

Electron Trapping Optical Media (ETOM)

1 Mil bits of information per cubic micron

Uses light: no degradation of media but difficult to store

Tapered Laser

Decrease laser spot by one fifth and improve recording capacity by 5.

3D Cubic Storage

125 GB in area of sugar cube - Commercially available in 1998

Developed by UCSD - Funded by Rome Air Development Lab

"Pin" Technology

2 GB on pin 1" long - Available in 5-7 years

Developed by Los Alamos National Lab

Perpendicular Recording

Increase tape storage density by 5 times.

Blue Laser Technology

Will provide 325 MB per square inch.